Self-Adapting Botanical Tree Models in Computer Graphics

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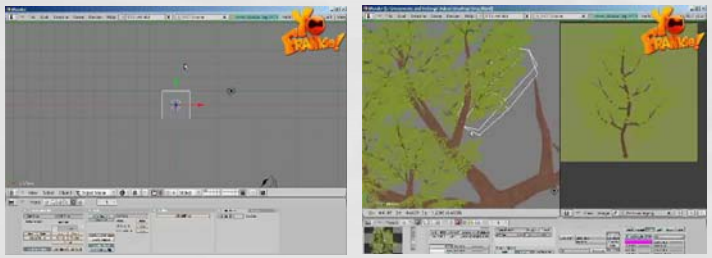
Jan 23rd 2014
Indiana Horticultural Congress

Modeling

- Modeling is an open problem in CG
- Traditional approaches
  - Manually
  - Scanning (and reconstruction) of real objects
  - By a code
- How does it relate to biology?

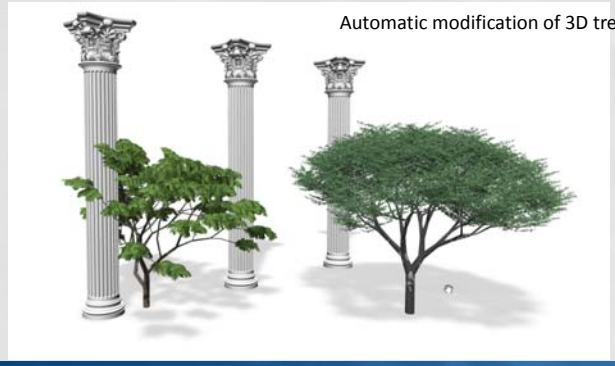
Modeling



Pablo Vazquez - http://vimeo.com/7956756

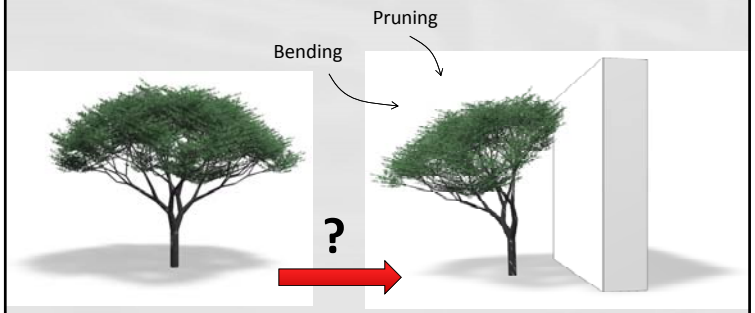
Tree models are static

Plastic Trees



Automatic modification of 3D tree models

Approach



Overview

Analysis

- Computing Branch Age
- Temporal Light Conditions
- Inverse Tropism
- Pruning Estimation

Realization

- Tree Graph Transformations
- Modeling of Leaf-Clusters
- Types of Interaction

Verification

- Evaluation
- Limitations
- Results

Input

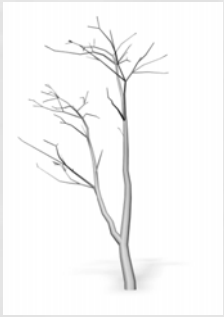
[Livny et al. 2011]

Skeletal Graph

+

Leaf Clusters

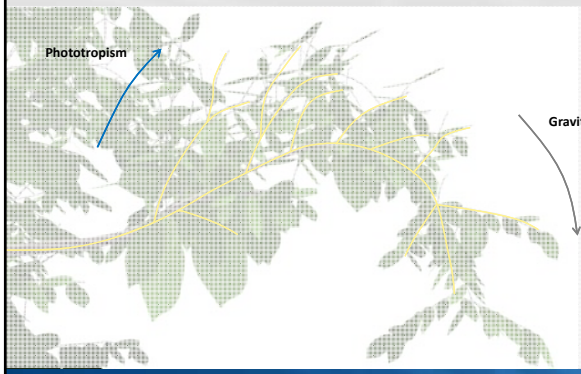
Tree Analysis



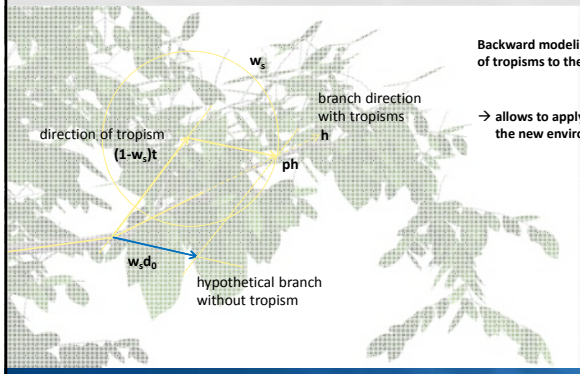
Skeletal graph:

- **branch age**
- **growth rate**

Tropism



Inverse Tropism

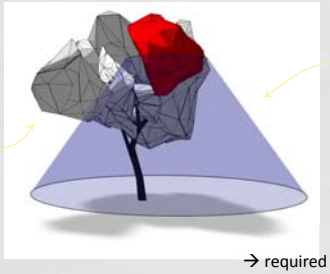


Backward modeling to estimate influence of tropisms to the original model

→ **allows to apply tropisms triggered by the new environment**

Tree Analysis

How much light is cast onto a part of a tree?



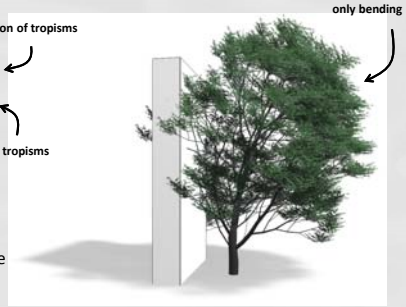
→ required for bending/pruning

Dynamic Interaction - Bending

New Direction

$$\vec{h} = w_s\vec{d}_0 + (1 - w_s)\frac{\sum w_\tau \vec{t}_\tau}{\sum w_\tau}$$

new direction
start weight
normalized direction
combination of tropisms
weights of tropisms



Transformations represent changes in the tree growth.

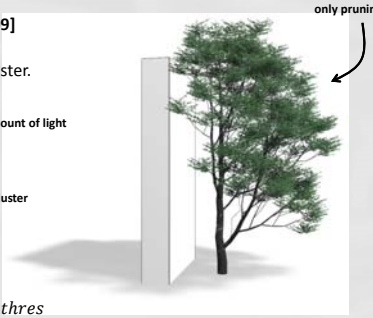
Dynamic Interaction - Pruning

Approach similar to **[Palubicki et al. 2009]**

Amount of Light received by the leaf-cluster.

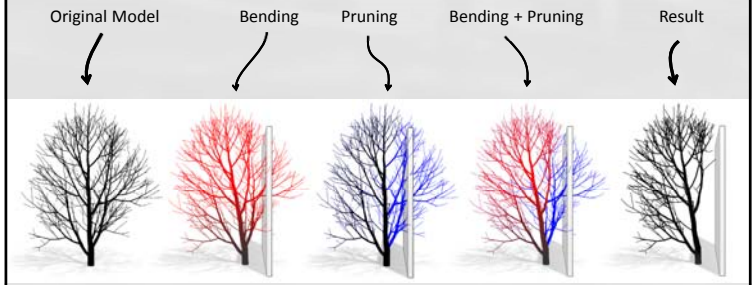
$$\varphi_{t_s} = \sum_{c \in C_s} 2\pi {r_c}^2 i_c$$

normalized amount of light
amount of resources (light)
radius of a given cluster
l_t: sum of distances



Branch is pruned when ratio $\varphi_{t_s}/l_t < thres$

Dynamic Interactions



Dynamic Interactions - Leaves

Intermediate Representation

Final Rendering

Evaluation

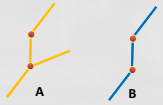
How to measure the distances between two trees?

Approach proposed by **[Ferraro and Godin 2000]** and **[Zhang 1996].**

Constrained edit distance between tree graphs.

Possible edit operations:

- **Deletion**
- **Insertion**
- **Change**

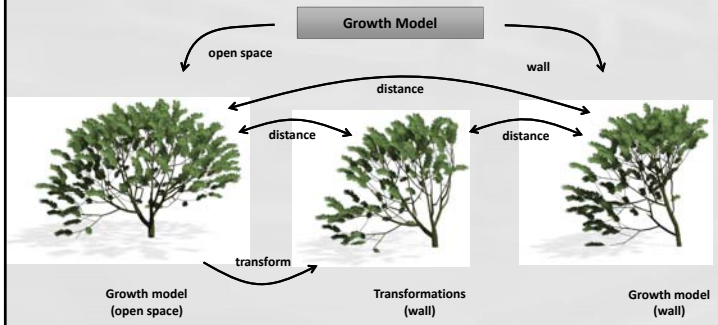


How much does the transformation from A to B cost?

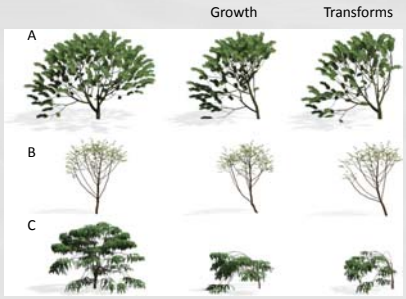
→ low costs → high similarity

Dissimilarities between two trees can be measured as edit distances of the graphs.

Evaluation



Evaluation

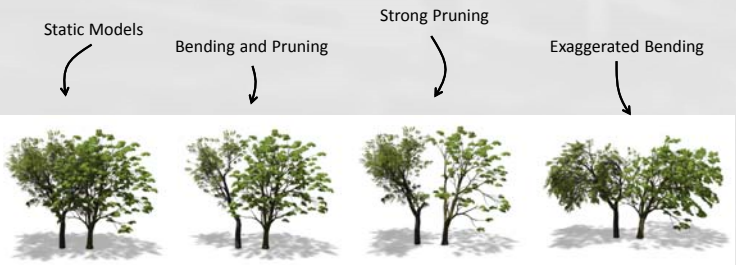


	Groups	T-G	G-G	T-G	T-T
Tree A	Mean	236.29	229.65	347.19	225.38
	SD	35.27	52.71	91.33	33.94
	p-value	p = 0.46		p < 0.001	
Tree B	Mean	431.73	396.81	471.63	413.64
	SD	112.79	71.32	70.65	90.76
	p-value	p = 0.06		p = 0.001	
Tree C	Mean	756.27	841.79	927.64	550.63
	SD	266.84	239.57	207.85	83.33
	p-value	p = 0.13		p < 0.001	

No significant distance between growth and transforms.

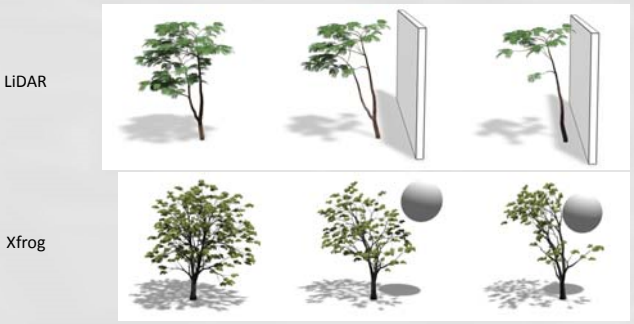
Tree-tree interaction

Tree-tree interaction



Tree-tree interaction

Results



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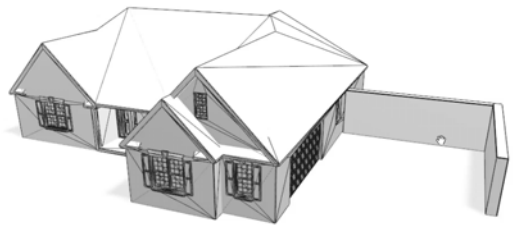

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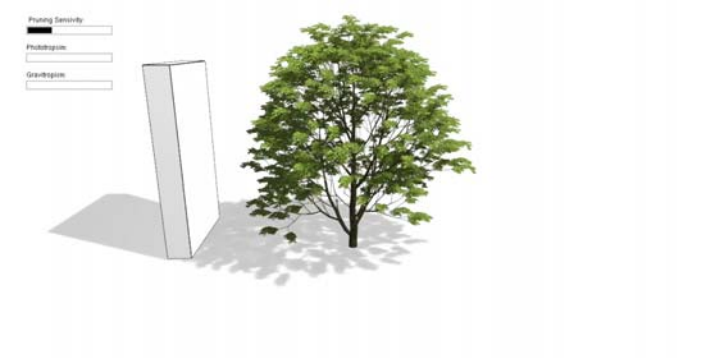

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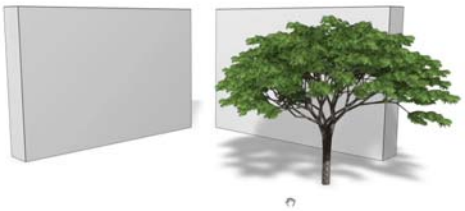

Conclusions

- Visual modeling is a very strong concept
- Precise geometry can improve biological models
- Inverse methods *are very interesting*
- Computer graphics deals with light and geometry, so does biology…